The Small Lakes of Sammamish

A Report on Water Quality Monitoring Results
for Water Year 2011 at Pine and Beaver Lakes

Beaver Lake – main basin

Prepared for the City of Sammamish
by the King County Lake Stewardship Program

February 5, 2012

King County

OVERVIEW

The King County Lake Stewardship Program and its predecessor programs have worked with volunteer monitors for more than 18 years on Pine Lake and the two basins of Beaver Lake within the City of Sammamish. The water quality data indicate that in general, Pine Lake and Beaver-2 are low to moderate in primary productivity with good water quality, while Beaver-1 has been and continues to be highly productive, indicative of the input from the nearby wetland to the north that constitutes its major surface water source.

Both Beaver Lake and Pine Lake have public access boat launches and parks with beach front, where members of the public are able to access the lakes. At present, no invasive noxious aquatic weeds have been reported for either lake aside from fragrant water lily. However, residents should keep a watch on aquatic plants growing submersed or near shore to catch early infestations of Eurasian milfoil, Brazilian elodea, or other noxious weeds.

This report refers to two common measures used to predict water quality in lakes. The Trophic State Index or TSI (Carlson 1977) is a method of calculating indicators from collected data that allows comparison between different parameters and predicts the volume of algae that could be produced in the lake. A second measure is the nitrogen-to-phosphorus ratio (N:P), which is used to predict what groups of algae may become dominant in the lake during certain periods. Both the TSI and N:P ratios have been calculated using data collected through the volunteer monitoring program.

The discussion in this report focuses on the 2011 water year. Specific data used to generate the charts in this report can be downloaded from the King County Lake Stewardship data website at:

http://www.metrokc.gov/dnrp/wlr/water-resources/small-lakes/data/default.aspx.

Or can be provided in the form of Excel files upon request.

BEAVER LAKE

In the mid-nineties, residents at both basins of Beaver Lake (Figure 1: smaller north basin referred to as Beaver-1 and large main basin referred to as Beaver-2) began monitoring water quality through participation in the King County Lake Stewardship Program (KCLSP). Volunteer monitoring efforts have continued through 2011. Physical and chemical data collected through the years of monitoring indicate that this lake in the City of Sammamish is moderate (Beaver-2) to high (Beaver-1) in primary algal productivity (mesotrophic and eutrophic, respectively), with fair to very good water quality.

Figure 1. Aerial photo of Beaver Lake showing both lake basins. A third small basin that contains the outlet is located in the bottom left of the figure.

Physical Parameters

Excellent precipitation and water level records were kept for the main basin (Beaver-2) through June of 2011, when the volunteer moved away. A new volunteer has been recruited and will begin recording measurements soon.

Water levels in Beaver-2 increased in response to storm events (Figure 2). Although lake level measurements stopped in June, it is likely that a pattern similar to previous years and characteristic of the regional pattern of winter high–autumn low stands was seen in Beaver 2 during the rest of the season. Precipitation and lake level data show the lake does rise with the onset of autumn rains and remains elevated through the winter and into spring. Typically, the highest lake levels do not usually persist longer than a few days to a week when the outlet is flowing freely, but there have been instances in the past when the outlet weir has been clogged with debris and when beaver activity has plugged the outlet channel, leaving lake levels higher.

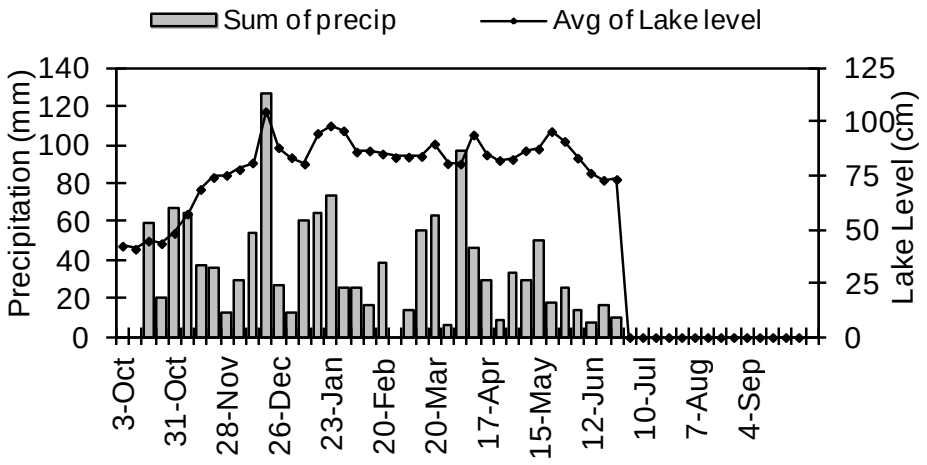

Figure 2. WY 2010 Beaver-2 Lake Level and Precipitation

Residents on Beaver-1 did not collect daily precipitation or lake level information, but the channel between the two lakes rarely shows perceptible flow between the water bodies. Continuous lake level measurements made by the King County hydrology group for the Beaver Lake Management District have shown that water levels are generally equivalent between the two basins.

Beaver-2 Level I volunteers collected weekly temperature and Secchi transparency data until June of 2011 (Figure 3). A different Level II volunteer collected water samples for laboratory analyses from early May through late October, and at the same time made temperature and Secchi measurements. Secchi transparency measured by the Level I volunteer through June ranged between 1.9 m and 2.8 m. The data from the Level II volunteer, measuring from May through October only, ranged from 2.3 to 3.5 m, with a summer average of 2.7 m.

Observers can vary in how they read the endpoint of the Secchi test, depending on their ability to differentiate subtle changes and how their vision reacts to glare off the water surface, the type of boat they are using, and how close to the water surface they can safely view the disk. Therefore, it is not surprising when there is a small systematic difference between the two observers, which even occurs among professionally trained field crews. It is important to be consistent in examining one observer's measurements over time and, if at all possible, to calibrate differences by collecting concurrent measurements between observers for comparison.

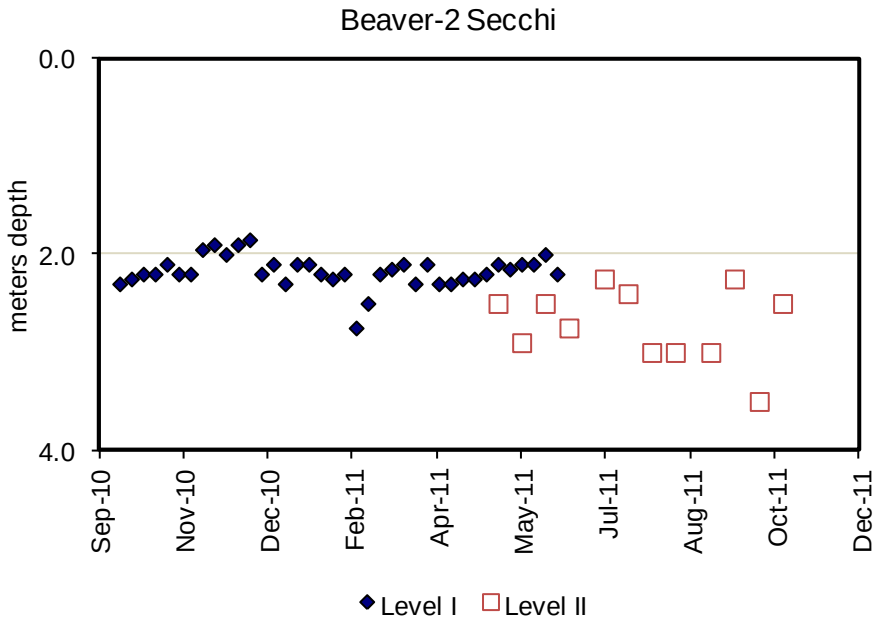

Figure 3. 2011 Beaver-2 Lake Secchi Transparency

Surface water temperatures ranged between 4.0 to 22.0 degrees Celsius over 2011 with a May – October average of 18.3 degrees Celsius (Figure 4). The recorded maximum temperature was in the midrange of values reported among the group of monitored lakes.

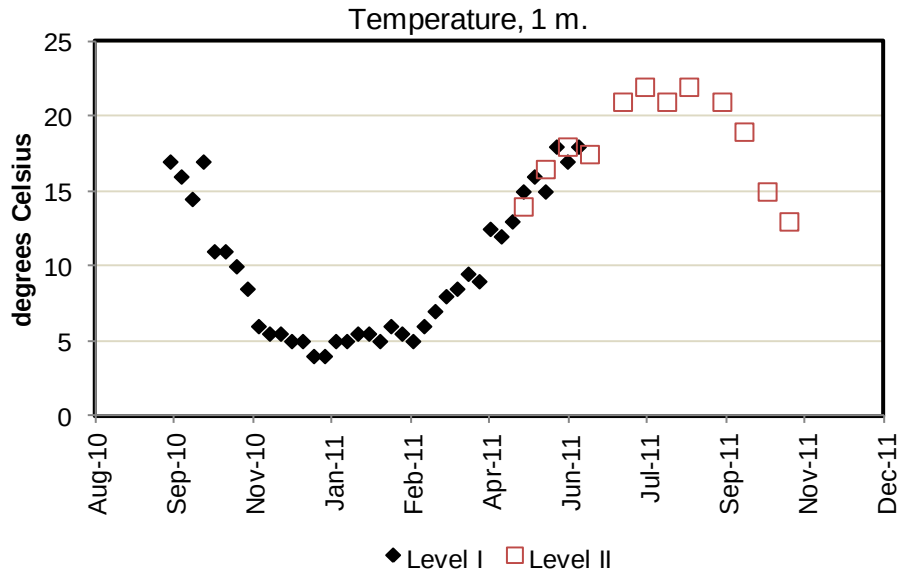

Figure 4. 2010 Beaver-2 Lake Water Temperatures

The north basin (Beaver-1) was monitored for Secchi transparency and water temperature during the Level II monitoring season from early May to the end of October 2011. **Transparency** ranged from 0.2 m to 1.8 m with an average of 1.0 m (Figure 5). Beaver-1 is at the lower end of clarity for the lakes monitored by the KCLSP in 2011 due to the tea-colored water coming from wetland ELS 21 that drains directly into the basin. In addition, a large bloom of *Anabaena planctonica* obscured water clarity from late summer through fall, giving the water a pea soup appearance (Figure 6).

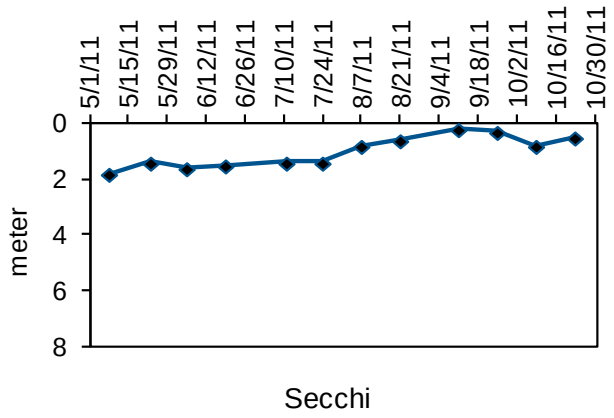

Figure 5. 2011 Beaver-1 Secchi Transparency

Figure 6. Water appearance of Beaver-1 during *Anabaena planctonica* bloom in September 2011

Temperatures for Beaver-1 ranged from 12.5 degrees Celsius to 22.0 degrees Celsius with an average of 18.0 degrees Celsius (Figure 7) that places the north basin of Beaver Lake among the cooler lakes measured during the 2011 sampling season.

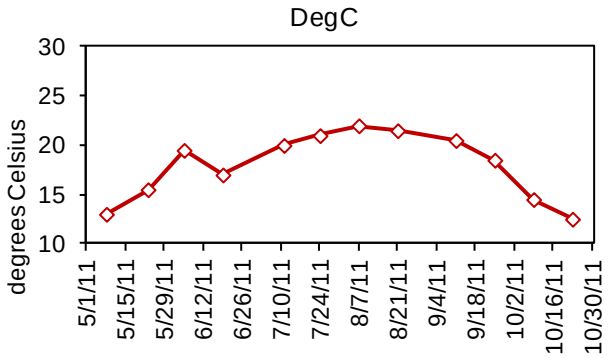

Figure 7. 2011 Beaver-1 Lake Water Temperatures

Nutrient and Chlorophyll Analysis

Nutrients

Phosphorus and nitrogen are naturally occurring elements that are necessary in small amounts for both plants and animals. However, many actions associated with residential development can increase concentrations of these nutrients beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is often the nutrient in least supply, meaning that biological productivity is often limited by the amount of available phosphorus. Increases in phosphorus concentrations can lead to more frequent and dense algae blooms – a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by species that can produce toxins. Samples collected by volunteers are analyzed for total phosphorus (TP) and total nitrogen (TN) concentrations at one meter depth.

During the monitoring period, Beaver-2 TN values decreased through the spring but took a slight jump in mid July, then remained relatively table until fall when they began to climb again (Figure 8). TP slightly increased in early June, but was relatively stable throughout the majority of the remainder of the season. Levels also increased in October similar to TN.

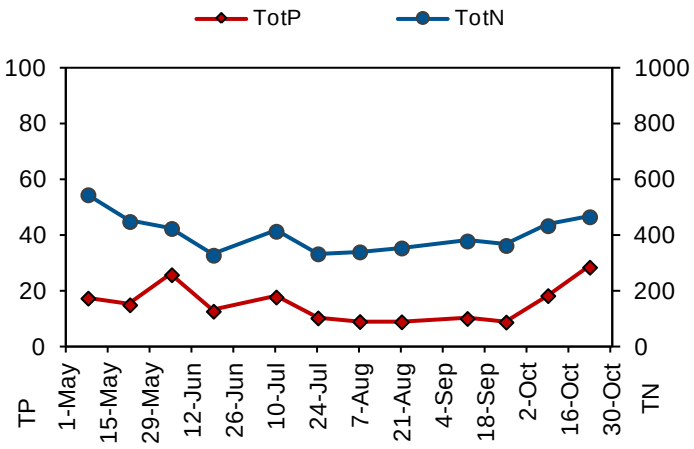

Figure 8. 2011 Beaver-2 Total Phosphorus and Total Nitrogen Concentrations

Beaver-1 had much higher levels overall of both TP and TN (Figure 9). TN increased drastically in early August through early September and then gradually decreased from late September to October. This was concurrent with the *Anabaena* bloom mentioned in the section on Secchi transparency. Interestingly, TP did not echo this increase and was mostly stable throughout the sampling season.

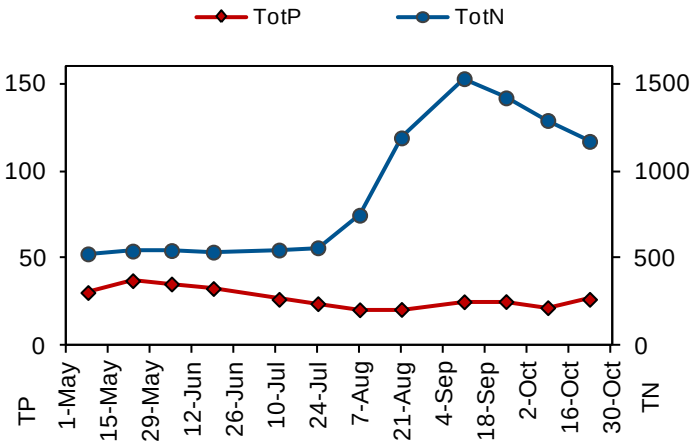

Figure 9. 2011 Beaver-1 Total Phosphorus and Total Nitrogen Concentrations

N : P ratios

The ratio of nitrogen to phosphorus (N:P) can be used to determine if nutrient conditions are favorable for the growth of cyanobacteria (bluegreen algae) that can impact beneficial uses of the lake. When N:P ratios are near or below 20, cyanobacteria often dominate the algal community due to their ability to take nitrogen from the air.

Beaver-1 ranged from 14.6 to 61.4 with an average of 35. Throughout May and into July the N:P ratios were below or near 20, which suggested that the spring provided nutrient conditions that were favorable for nuisance bluegreen algae growth. Once *Anabaena* became abundant, the TN soared, appearing as if nutrient conditions were no longer favorable for increased growth. However, the large abundance of the *Anabaena* already present likely excluded any other species from being competitive and the buoyancy of the species kept it high in the water column.

In Beaver-2, total phosphorus and total nitrogen ratios remained in relatively constant proportion to each other through the sampling period, with only one value below 20 and an average of 29.5, which suggests that nutrient conditions in the lake were generally not favorable for nuisance bluegreen growth in 2011.

Chlorophyll a

Chlorophyll concentrations relate to the amount of algae present in lake water. All algae must have chlorophyll in order to fix energy from sunlight, so higher amounts of chlorophyll denote more abundant algae. However, some of the cyanobacteria (bluegreen algae) also use other pigments to capture light, so their relative amounts of chlorophyll per cell volume may be smaller than for other groups of algae. Pheophytin is a degradation product of chlorophyll, and large amounts present in a sample can indicate the presence of sediment detritus or other sources of old chlorophyll, in addition to that contained in vibrant, living algae. Some of these additions can be caused by wind and rain storms, sediment disturbance, bank erosion, or wash-in from watershed activities.

Chlorophyll *a* concentrations in Beaver-2 see-sawed between low and moderate levels throughout the season, with a peak in fall. Pheophytin (degraded chlorophyll) levels were above detection levels, but remained low with the exception of the first date in May (Figure 10).

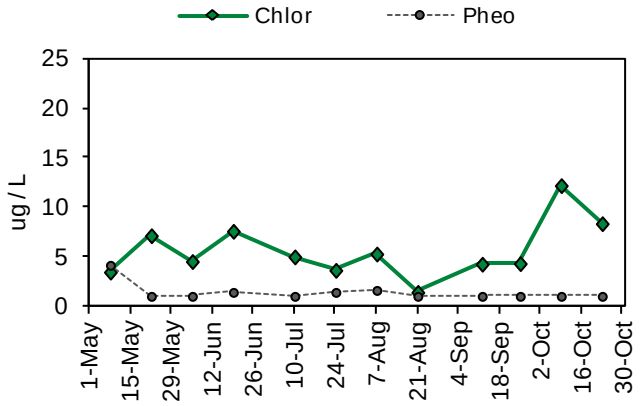

Figure 10. WY 2011 Beaver-2 Chlorophyll *a* and Pheophytin concentrations

In Beaver-1, chlorophyll *a* concentrations were moderate with one very high peak in lake September that likely lasted through October (Figure 11). During the fall there was a large *Anabaena planktonica* bloom beginning in late summer that persisted through fall. The high chlorophyll values were accompanied by a significant rise in TN, but this was not reflected in TP values. The majority of the pheophytin levels were below detection levels throughout the period.

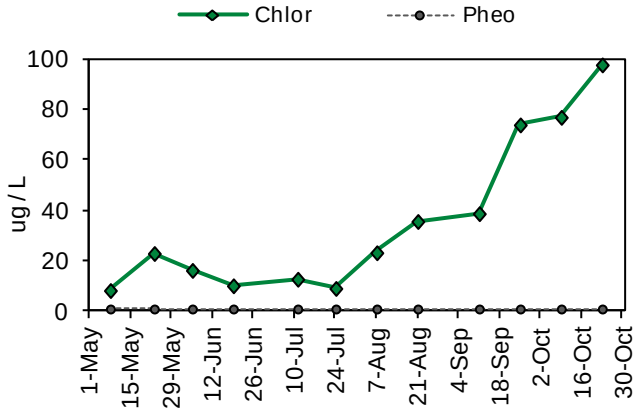

Figure 11. WY 2011 Beaver-1 Chlorophyll *a* and Pheophytin concentrations

Water column profiles

Profile data on Beaver-2 indicates that thermal stratification was present from early summer and persisted through late summer (Table 1). Higher concentrations of total phosphorus were found in deep water in May, but especially in August, suggesting that anoxia could have triggered a release of phosphorus from the sediments in summer as shown by the phosphate (OPO4) values throughout the summer. Ammonia (NH3) concentration, which is another indicator of low oxygen conditions in the deep water, was not very high in May but was significantly elevated in August, indicating that anoxia in the deep water increased through the summer.

Chlorophyll *a* profile data indicated that the highest concentrations of phytoplankton are in the surface of the lake in the May profile date ,while in August the majority of the phytoplankton was present at mid-depth. Both dates have moderately low chlorophyll concentrations overall, suggesting the lake did not support an abundance of phytoplankton and had relatively low biological productivity.

Table 1. Beaver-2 Profile Sample Analysis Results. Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 is in absorption units. Sample values below minimum detection level are marked <MDL.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Beaver-2	5/22/11	2.9	1	16.5	7.1	<MDL	0.450	0.007	0.0151	0.0025	0.241	13.7
Beaver-2	5/22/11		7	16.0	6.4	<MDL	0.533		0.0119			
Beaver-2	5/22/11		14	12.0			0.525	0.006	0.0182	0.0061		
Beaver-2	8/21/11	3.0	1	22.0	1.4	<MDL	0.355	0.008	0.0090	<MDL	0.214	15.8
Beaver-2	8/21/11		7	8.5	4.6	<MDL	0.407		0.0133			
Beaver-2	8/21/11		14	8.0			0.442	0.126	0.0567	0.0115		

The UV254 value shows that some tea coloration is present in the water of Beaver-2 and represents a moderate level of dissolved organic carbon, while the total alkalinity represents soft water that is not well buffered against pH change.

Profiles from Beaver-1 (Table 2) showed that thermal stratification set up in the lake in early spring and lasted through late summer. TP and TN levels were slightly elevated at the deeper sample in May and were accompanied by significant ammonia (NH3) concentrations, suggesting that oxygen was already being depleted near the bottom. That was confirmed in the August profile with elevated TN, TP, orthophosphate (OPO4), and ammonia at 14 meters in Beaver-1.

Chlorophyll *a* data suggest the most algae are found in the surface water rather than spread throughout the water column. The chlorophyll levels were particularly high in August in the 1 m sample, which coincides with a large anabaena bloom that persisted throughout much of late summer and early fall. However, the profile data suggests that the algae bloom was confined to the shallow water only and did not extend very deeply into the lake.

Table 1. Beaver-1 Profile Sample Analysis Results. Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 is in absorption units. Sample values below minimum detection level are marked <MDL.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Beaver-1	5/23/11	1.4	1	15.5	23.0	<MDL	0.540	<MDL	0.0370	0.0020	0.405	10.1
Beaver-1	5/23/11		7	5.0	2.1	<MDL	0.534		0.0282			
Beaver-1	5/23/11		14	5.0			0.607	0.006	0.0392	0.0214		
Beaver-1	8/21/11	0.6	1	21.5	35.7	12.8	1.190	0.005	0.0205	0.0024	0.439	11.2
Beaver-1	8/21/11		7	5.5	2.6	4.4	0.458		0.0200			
Beaver-1	8/21/11		14	5.0			0.656	0.200	0.1670	0.0527		

The high UV254 values are indicative of the marked tea color of the water produced by dissolved organic carbon molecules leached from the upstream wetland,. The low alkalinity value shows that the lake water is very soft and quite poorly buffered against pH change.

TSI Ratings

A common method of tracking water quality trends in lakes is by calculating the "trophic state index" (TSI), developed by Robert Carlson in 1977. TSI indicators predict the biological productivity of the lake based on water clarity (Secchi) and concentrations of TP and chlorophyll *a*. A value of 50 or higher indicates eutrophy, or a highly productive lake in terms of algae, while values below 40 indicate oligotrophy, or low rates of productivity. Values between 40 and 50 are considered moderate or mesotrophic.

The 2011 Beaver-2 TSI indicators for chlorophyll *a* and Secchi were very close to each other in the medium range of mesotrophy, down from the values in 2009 when there was an *Anabaena* bloom similar to the bloom in Beaver-1 this year. The TSI-TP indicator was lower than the other two indicators (Figure 12). The TSI indicators in 2011 were similar to 2010 and slightly lower than 2009, but the trend over the series appears flat since 1998, and Beaver-2 remains in the mid mesotrophic range.

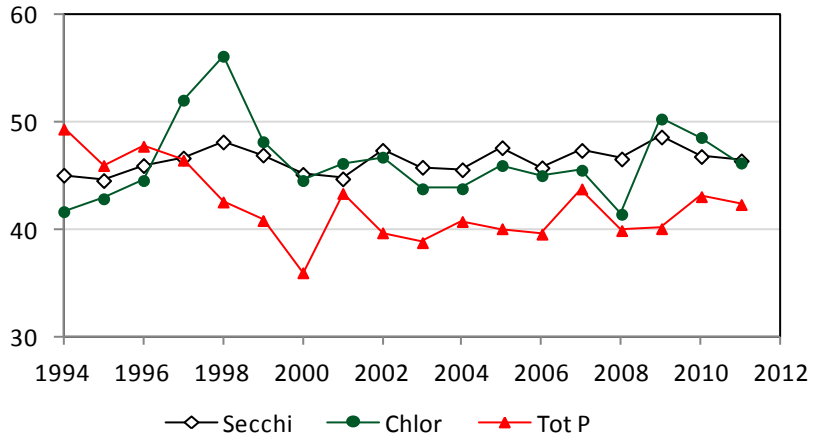

Figure 12. Beaver-2 Trophic State Indicators through 2011

In 2011, the TSI indicators for chlorophyll a and Secchi in Beaver-1 were close to each other in the upper range of eutrophy, and the TSI-phosphorus indicator was in the lower end of eutrophy (Figure 13). The chlorophyll TSI increased considerably in 2011 due to the *Anabaena* bloom in late summer and early fall, which also affected the TSI-Secchi value. Phosphorus was only slightly lower than the 2010 value, which was the highest value since 1998. If a trend line is drawn through the entire series, there is no significant change over time. However, a slight, but steady increase has been seen in this basin since 2002, and a close watch should be kept on phosphorus as development proceeds in the upper watershed.

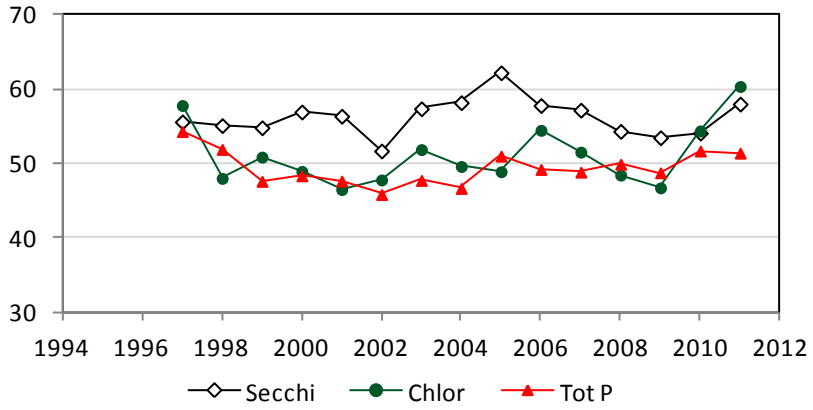

Figure 13. Beaver-1 Trophic State Indicators through 2011.

Conclusions and Recommendations

Based on monitoring data, water quality in Beaver-2 appears to be stable over the period measured, and the avergae N:P ratio is not conducive to creation of nuisance bluegreen algae blooms, although the bloom in 2009 shows that some species can occasionally predominate in the absence of a favorable N:P ratio.

In Beaver-1, there is a suggestion of an increase in phosphorus concentrations since 2002, but it is not a statistically robust trend at this time. Similar to Beaver-2 in 2009, there was a species of *Anabaena* dominating the phytoplankton in late summer through fall. This algae created a nuisance, but did not produce toxins that could have threatened human or pet health and safety. Continued monitoring of nutrient and chlorophyll concentrations should be done to insure recreational safety and to assess water quality conditions into the future as development in the watershed proceeds.

PINE LAKE

Physical Parameters

Excellent precipitation and water level records for Pine Lake were compiled by the volunteer monitor for the 2011 water year. Water levels in the lake responded to winter storm events, but remained relatively steady until late June when the water level began a slowly decrease over the remainder of the water year. Overall, the lake followed the regional pattern of winter high–autumn low stands. Precipitation and lake level data collected since 1995 suggest the lake rises with the onset of autumn rains and remains somewhat elevated through the winter and into spring. However, the highest lake levels do not usually persist longer than a week or two (Figure 1).

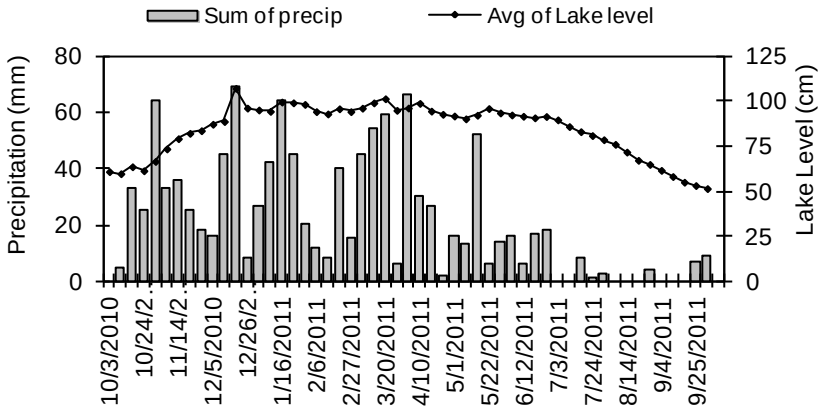

Figure 1. WY 2011 Pine Lake Level and Precipitation

Pine Lake volunteers collected weekly temperature and Secchi transparency data throughout the 2011 water year in addition to values collected during the "Level 2" monitoring season from early May through late October. Secchi transparency ranged between 2.5 and 6.7 m (Figure 2). The annual average was 5.0 m and the summer average was 4.5 m, which placed it in the higher range for monitored small lakes in 2011. A couple of unusual low transparency values were recorded in April, likely caused by a spring diatom bloom, but the condition did not persist.

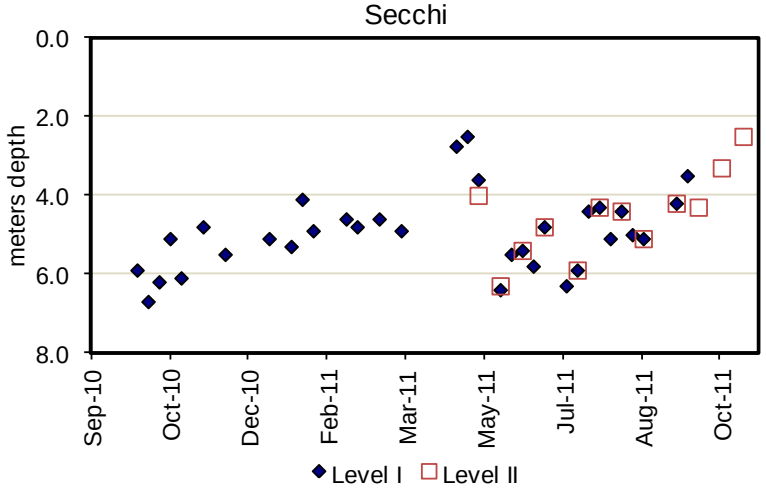

Figure 2. Pine Lake Secchi Transparency

Surface water temperatures ranged between 3.5 to 24.0 degrees Celsius over 2011, with an annual average of 14.2 and a summer average of 19.4 degrees Celsius (Figure 3). The recorded maximum temperature was in the midrange of values reported among the group of monitored lakes.

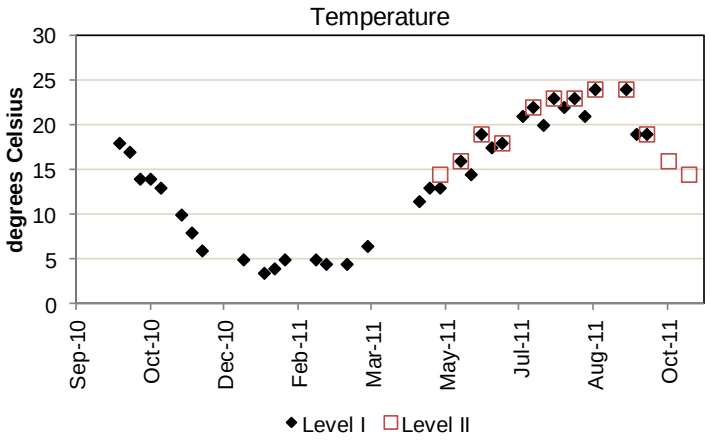

Figure 3. Pine Lake Water Temperatures

Nutrient and Chlorophyll Analysis

Phosphorus and nitrogen are naturally occurring elements that are necessary in small amounts for both plants and animals. However, many actions associated with residential development can increase concentrations of these nutrients beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is often the nutrient in least supply, meaning that biological productivity is often limited by the amount of available phosphorus. Increases in phosphorus concentrations can lead to more frequent and dense algae blooms–a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by species that can produce toxins. Samples collected by volunteers are analyzed for total phosphorus (TP) and total nitrogen (TN) concentrations at one meter depth.

During the monitoring period for Pine Lake, TN and TP values remained relatively constant throughout the sampling season, with little variation over time (Figure 4).

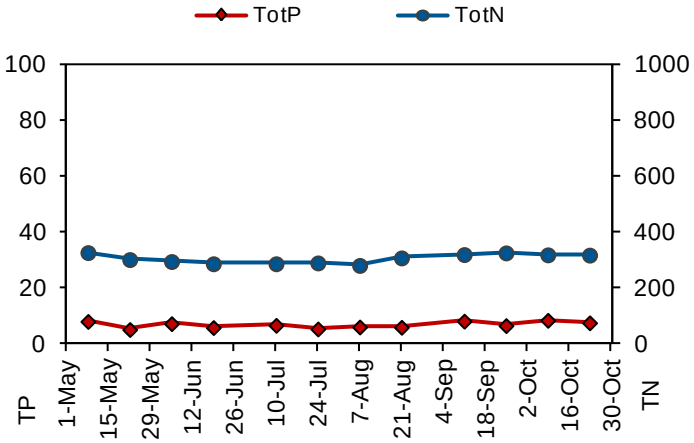

Figure 4. 2011 Pine Lake Total Phosphorus and Total Nitrogen Concentrations in µg/L

The ratio of nitrogen to phosphorus (N:P) can be used to determine if nutrient conditions are favorable for the growth of cyanobacteria (bluegreen algae) that can impact beneficial uses of the lake. When N:P ratios are near or below 20, cyanobacteria often dominate the algal community due to their ability to take nitrogen from the air. In Pine Lake, total phosphorus and total nitrogen remained in relatively constant proportion to each other through the sampling period, ranging from 38.3 to 60.2 with an average of 47.1, which suggests that nutrient conditions in the lake were not favorable for nuisance bluegreen blooms.

Chlorophyll concentrations relate to the amount of algae present in lake water. All algae must have chlorophyll in order to fix energy from sunlight, so higher amounts of chlorophyll denote more abundant algae. However, some of the cyanobacteria (bluegreen algae) also use other pigments to capture light, so their relative amounts of chlorophyll may be smaller than for other groups of algae. Pheophytin is a degradation product of chlorophyll, and large amounts present in a sample can indicate that the presence of sediment or other detritus containing old chlorophyll in addition to that contained in vibrant, living algae. Sources include inputs from wind and rain storms, sediment disturbance, bank erosion or wash-in from watershed activities.

Chlorophyll *a* concentrations in Pine Lake also remained low throughout most of the sampling season with a peak in late fall (Figure 5). Pheophytin (degraded chlorophyll) levels remained below detection levels throughout the season.

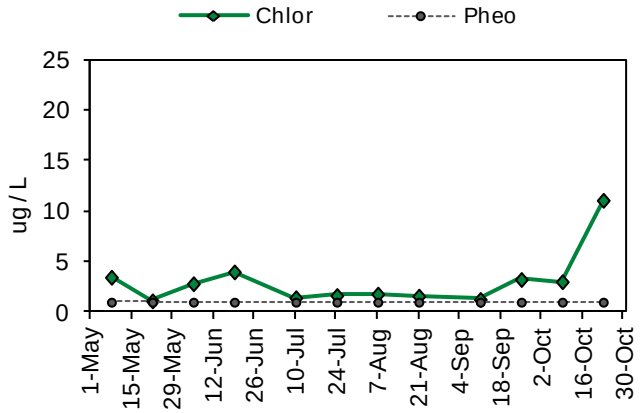

Figure 5. WY 2011 Pine Lake Chlorophyll *a* and Pheophytin concentrations

Profile data on Pine Lake indicates that thermal stratification was present in early summer and persisted through late summer (Table 1). Higher concentrations of phosphorus were found in deep water in May and especially in August, suggesting that the oxygen is the deep water was becoming depleted and phosphorus was being released from bottom sediments. Ammonia (NH3) was detected in May and had increased by August, confirming anoxia in the deep water. However, the phosphate (OPO4) values remained fairly low, as did chlorophyll values, suggesting that phosphorus recycling from the sediments was not having a major effect on phytoplankton abundance.

Both profile dates have similar chlorophyll concentrations at both shallow and mid-depths, showing that the lake had very little phytoplankton in the zone that sunlight penetrates, with generally low biological productivity.

Table 1. Pine Lake Profile Sample Analysis Results. Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 is in absorption units. Sample values below minimum detection level are marked <MDL.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Pine	5/22/11	6.3	1	16.0	1.1	<MDL	0.301	0.010	<MDL	<MDL	0.078	22.9
Pine	5/22/11		5	13.0	1.7	<MDL	0.318		0.0078			
Pine	5/22/11		10	8.0			0.505	0.104	0.0191	0.0028		
Pine	8/21/11	5.1	1	24.0	1.6	<MDL	0.307	<MDL	0.0058	<MDL	0.069	23.0
Pine	8/21/11		5	21.0	2.0	<MDL	0.292		<MDL			
Pine	8/21/11		10	9.0			0.810	0.348	0.0814	0.0112		

The UV254 values were indicative of clear water with little dissolved organic carbon, unlike the tea color of the water in Beaver Lake that indicates high concentrations and impacts water clarity. The alkalinity value, while still low, is higher than those found in Beaver Lake. This may relate to the higher degree of development and soil disturbance in the Pine Lake watershed. However, Pine Lake water still has fairly soft water that is poorly buffered against pH change.

TSI Ratings

A common method of tracking water quality trends in lakes is by calculating the "trophic state index" (TSI), developed by Robert Carlson in 1977. TSI indicators predict the biological productivity of the lake based on water clarity (Secchi) and concentrations of TP and chlorophyll *a*. A TSI value of 50 or higher indicates eutrophy, or a highly productive lake in terms of algae populations, while values below 40 indicate oligotrophy, or low rates of productivity. Values between 40 and 50 are considered moderate or mesotrophic.

The 2011 Pine Lake TSI indicators for chlorophyll *a* and Secchi were fairly close to each other on either side of the threshold between oligotrophy and mesotrophy, while the TSI–TP indicator was in the lower end of the oligotrophic range and was significantly lower than the other two values (Figure 6). The average of all three TSI indicators in 2011 was consistent with previous years, suggesting that conditions in Pine Lake are stabilized in the upper ranges of oligotrophy. There is the possibility of a slight decrease in TSI-TP over the course of the last several years but more years need to be collected to test for robust statistical significance in the possible trend.

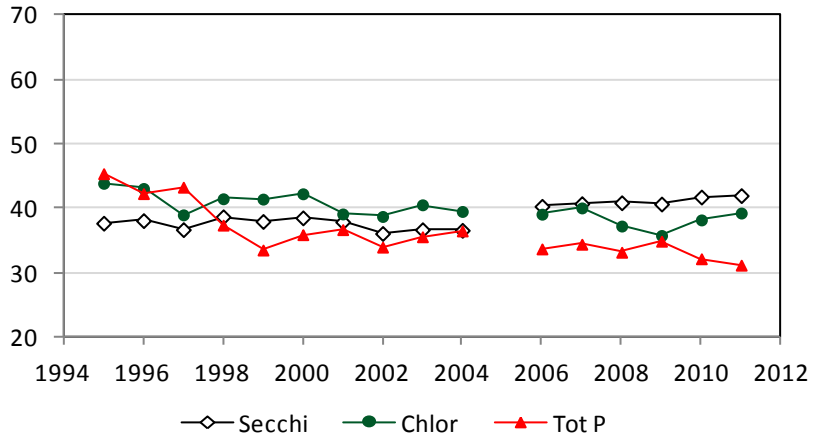

Figure 6. Pine Lake Trophic State Indicators through 2011

Conclusions and Recommendations

Based on monitoring data, water quality in Pine Lake appears stable over the period measured with a low rate of productivity in the summer months. High average N:P ratios could indicate nutrient conditions are generally not favorable for nuisance bluegreen algae blooms. Continued monitoring of nutrient and chlorophyll concentrations will assess future conditions and track any changes , as well as providing enough data to assess the statistical significance of the apparent decline in TP over time.